Enhancement of degraded Document Images using Retinex and Morphological Operations

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***Abstract*— Ancient historical inscriptions collected from various sources are image captured and stored as document images in digital libraries. Due to various factors, such as aging, degradation, erosion and deposition of foreign bodies on the inscriptions the quality of images captured is poor. These images are not ready for further processing such as reading, translation and indexing. Image Enhancement is an important phase for such document images before extracting information. A novel hybrid enhancement process has been proposed in this paper to highlight the text in the inscription, to make it more suitable for recognition using an OCR (Optical Character Recognition) system. The proposed method is a combination of Frankle McCann Retinex approach and Morphological operations which highlight the image contours by suppressing the background deformation and noise. The method is tested on a dataset of 300 camera captured estampage images of stone inscriptions written in ancient Kannada script. Experimental results show the efficacy of the proposed method.**

Keywords- Frankle McCann Retinex; Thickening; Filling; Inscription images

Introduction

Inscriptions carved on stone, palm leaves, metal and shells are the historical documents which serve as the solitary and authentic records for understanding ancient history. These recorded experiences are useful in countless ways for the study and reconstruction of the social, economic, cultural, dynastic and political history of the mankind. Preservation of these documents is irrefutable if they must continue to serve as a reference in making further discoveries about the world. Unfortunately, these copies are at a serious risk of loss and extinction as they are deteriorating due to aging, natural disasters, risky handling, depositions and harsh weather conditions. To preserve these valuable archaeological resources for future the Archaeological departments throughout the world excavate these inscriptions from their sources, create their Estampages and maintain a corpus of the same. But Estampages can also deteriorate in the long run due to breakage, aging, risky handling, dust and insects.

Digitization of these images is a more reliable solution for their preservation. Digitization creates faithful reproduction of Estampages in the form of digital images by either image capture or scanning. Digital images have longer shelf life and are easy to access and disseminate. Moreover, they can further take advantage of the power of digital image enhancement, possibilities of structured indexes, machine recognition and translation, mathematics of compression and communication. These technological solutions are very much needed to motivate the Archaeological Departments to convert their repository of historical documents into a digital library and to automate information extraction from these documents. Moreover, these digital documents are more readily accessible to historians and researchers compared to the originals that are not easily available for public viewing.

However, these digital images would be inherently degraded as they are captured from a source which is already deteriorated. Therefore, to make them suitable for automatic machine recognition and translation it is inevitable to pre-process them using suitable image enhancement technique. Image Enhancement improves the perception of information in an image for human viewing and for further automated image processing operations. The proposed work is the first effort to enhance the camera captured estampages of the stone inscriptions belonging to the 11th century Kalyani Chalukyan dynasty. These handwritten inscriptions are in Kannada script

and are collected from the corpus of the public organization-Archaeological Survey of India.

The techniques for image enhancement can be broadly classified as local and global methods. Global approach is an overall enhancement approach where the entire image is modified as per the statistics of the whole image. But meanwhile the smaller details are lost because the number of pixels in these small areas has no influence on the computation of global transformation. Whereas local enhancement can enhance even the smaller details in the image as it uses a small rectangular or square neighborhood with the centre moving from pixel to pixel over the entire image. The centre pixel of the window is modified with a value calculated based on the statistics of the other pixels of the window. Local enhancement is preferable for inscription images since the separation between the foreground text and the background is not prominent. This paper presents one such enhancement approach based on Frankle McCann Retinex algorithm coupled with morphological processing. The rest of the paper is organized as follows: section I discusses related work, section II gives a detailed explanation of the proposed enhancement scheme, section III discusses the experimental results and discussion and section IV concludes the paper.

I. RELATED WORK

As available in the literature, the enhancement of Historical handwritten documents has been performed using Background light intensity normalization [29], directional wavelet transform [28], Background light intensity normalization [40] and Hyperspectral imaging [39].They mainly address the issues like background noise and ink bleed through. Specific to inscription image enhancement median filtering technique [32-35] has been used extensively. Curvelet transform [30] and shearlet tranform [31] in combination with morphological operations have been used to denoise south Indian palmscripts. Natural Gradient based Fast Independent Component Analysis technique has been employed to enhance stone inscriptions of Hampi [27]. But these techniques are not suitable for inscription estampage images as they might result in uneven contrast stretching.

Inscription images do not have clear visible difference between the foreground text and the background. Many times the deformation in the background would look like part of foreground text rendering poor visual appearance to these images. Retinex filtering [1, 3, 10, 11] is an enhancement method which compensates for non-uniform contrast by separating the illumination from the reflectance in a given image. It decreases the influence of the reflectance component, thus enhancing the original image to its true likeness. Hence it is more suitable for enhancement of Inscription document images. Although Retinex methodology had been used so far to enhance medical images[22], satellite images[21] ,natural scene images[5], nighttime images[20] and many more, it was only used for skew correction of document images[23] till [41] used it for contrast enhancement of inscription document images. The proposed enhancement scheme aims at improving the contrast enhancement results achieved by [41].

The Retinex algorithms published in the literature can be classified into four categories: Path based algorithms, Recursive algorithms, Center Surround algorithms and Variational algorithms. In path based algorithms the value of the new pixel depends on the product of ratios along the stochastic paths [11]-[14]. Recursive algorithms replace the path computation by a recursive matrix comparison [7]-[9]. These algorithms are computationally more efficient than the path based algorithms. In Center Surround method [3]-[5] a given pixel value is compared with the surrounding average pixel values to compute the new pixel. The variational Retinex algorithms [15]-[17] convert the constraints of illumination and reflectance into a mathematical problem and then obtain the new pixel value by solving equations or optimization problems. Morphological operations have been traditionally used as an effective tool for noise removal and enhancement of digital images [24-26].

Frankle McCann Retinex [7] algorithm, a recursive variant of traditional Retinex was found to be more suitable to highlight the text contours in the inscription image as it can stretch the image contrast simultaneously compressing the dynamic range rendering better visual clarity. Following which some morphological operations can be applied to suppress background noise and deformation. The following section provides the details of these techniques employed in the proposed method.

II. METHODOLOGY

The proposed enhancement scheme integrates Frankle McCann Retinex algorithm with Morphological Processing to enhance the inscription document images. Frankle McCann Retinex (FMR) algorithm [7] performs pixel level contrast stretching rendering sharp contrast to the entire image. To highlight the text contours and to suppress background noise and deformation, Morphological operations are performed on the Retinex enhanced images. The following subsections explain the FMR enhancement and the Background noise suppression in detail.

A. *Frankle McCann Retinex*

The principle of Frankle McCann algorithm [7] is shown in figure 1 below:

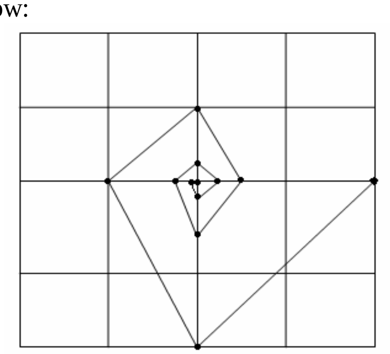

Figure 1: Principle of Frankle McCann Retinex Algorithm

At each step, the comparison is implemented using the Ratio-Product-Reset-Average operation. The process continues

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until the spacing decreases to one pixel. The Ratio- Product-Reset-Average operation is given by the equation:

$$r_p^{k+1} = (reset(i_{p\,-}\,i_q + r_q^{\,k}) + r_p^{\,k})\,/2 \qquad (1)$$

Where p is the neighborhood center pixel index and q is the index of one of the neighboring point. Let $p=(x,y)$, then $q \in \{(x\pm\ d^k\ ,y),\ (x,y\ \pm\ d^k\ )\}$, where d^k is the shift distance corresponding to the k-th update operation. In the iterative procedure, for a given p, q is spirally taken, and d^k is progressively reduced towards zero.

Since the operations are performed in logarithmic domain, the term is the ratio between the original intensity at p and that at q. The following addition is the product operation. Then the ratio- product term is reset to a constant whenever it exceeds the constant. And finally the reflectance estimation is updated by averaging the last estimation and the reset term.

B. *Morphological Operations*

The background noise pixels in the image produce artificial edges which are also enhanced by Retinex processing. These unwanted background edges interfere with the foreground text which hampers their visual clarity. In order to suppress these artifacts some morphological operations are performed on the binarized FMR output .The foreground text is accumulated into a connected component by applying Morphological Thickening, Filling and Bridging.

Thickening is the morphological dual of thinning. It is defined as

$$A\ \Theta\ B = A\ U\ (A\ \otimes B)\ C \qquad (2)$$

where A is the image matrix (set),

B is a structuring element suitable for thickening

$\otimes$ is the hit or miss transformation operation

T The morphological fill operation fills all the holes with ones for binary images. The hole filling algorithm first generates an array X_0. X_0 contains all zeros except at the location corresponding to the given point in each hole, which is set to one. This is followed by the following procedure:

$$X_k = (X_{k-1} \oplus\ B) \cap A^C \qquad k=1,2,3,\ldots. \qquad (3)$$

where B is the symmetric structuring element

$\oplus$ is the dilation operation

The algorithm terminates at the iteration step k if $X_k = X_{k-1}$. The set X_k then contains all the filled holes; the union of X_k and A contains all the filled holes and their boundaries. The dilation would fill the entire area if left unchecked. However, the intersection at each step with the complement of A limits the result to inside the region of interest.

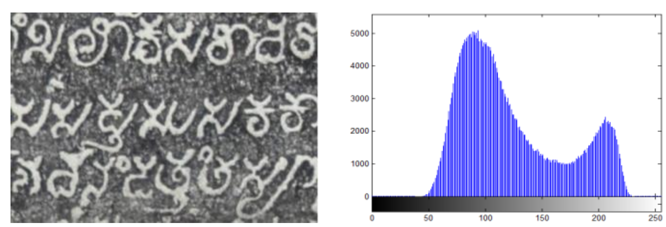
Bridging operation ties the unconnected pixels in the binary image by setting all zero valued pixels to one if they have two nonzero neighbours that are not connected. The objects signified by the connected components are assigned labels. For each object pixel summation is performed. If this sum is higher than the assumed threshold then the object is detected as valid text area and put into a mask image *M*. Finally the Region of Interest(ROI), that is the foreground text is extracted by computing Hadamard Product of *X* and *M* given by*:*

$$(X\ o\ M)_{i,j} \leftarrow (X)_{\,i,j}\,(M)_{\,i,j} \qquad (4)$$

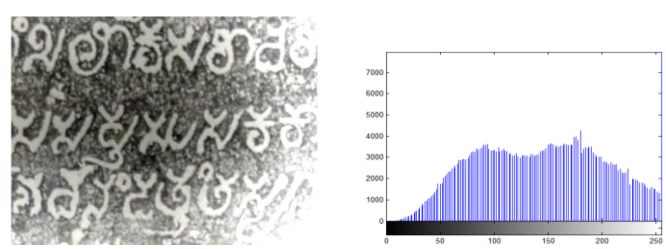
III. RESULTS AND DISCUSSION

The proposed Enhancement scheme is tested on the dataset of 300 camera captured images of ancient Kannada inscription Estampages that belong to the Kalyani Chalukyan era of 11th century. The images are captured using a camera of 13 Megapixel resolution. The visual quality of the original image as shown in Fig 2(a) is poor as it is infected by background noise and interference of the background pixels with the foreground text. Three different types of Retinex techniques namely Single Scale Retinex(SSR), MultiScale Retinex(MSR) and Frankle McCann Retinex (FMR) and the proposed method (FMR with Morphological operations) were tried on the dataset. SSR method enhanced the text but output resulted in significant greying out effect in some parts of the image as shown in Fig 2(b) leading to loss of some visual content. Quite a similar effect was observed with MSR as shown in Fig 2(c).

Frankle McCann Retinex algorithm is applied on the logarithmic version of the original image. The corresponding output is shown in Fig 2(d). Though the foreground text looks enhanced when compared to Fig 2(a), the overall image suffers from slight greying; a consequence of Retinex algorithm, also the unwanted artifacts gets enhanced. This might result in less accuracy of Optical Character Recognition to be performed later. So, to further enhance this result Morphological Processing is performed on the FMR output and the result is shown in Fig 2(e). Morphological Processing has removed the greyish look of the image and has improved the contrast by removing the unwanted background pixels making it more suitable for further processing steps.



(a)



(b)

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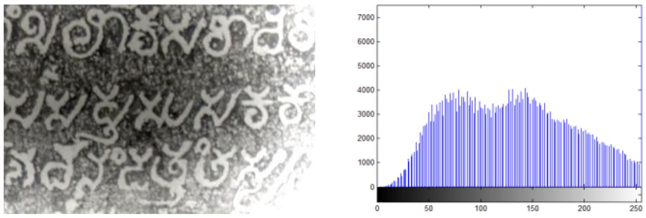
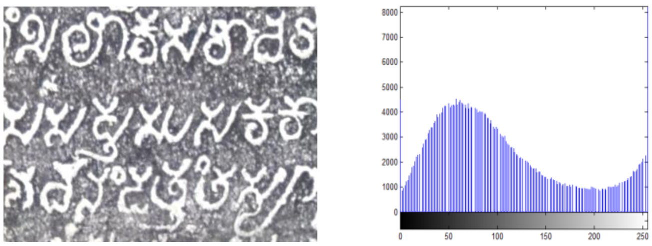
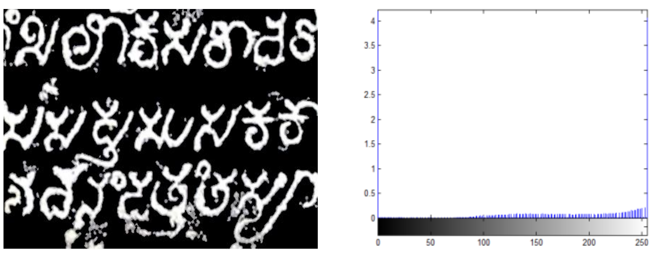


(c)



(d)



(e)

Figure 2 : The enhancement results achieved using the different Retinex approaches with the corresponding histogram plots (X-axis represents pixel intensity and Y-axis represents pixel count). (a) Original image (b) SSR (c) MSR (d) FMR (e) FMR with Morphological processing

Experimentation was done on our estampage dataset of 11th century Kannada stone inscriptions and also on the standard Handwritten text datasets-HDIBCO 2010, HDIBCO 2014 and HDIBCO 2016 to give a comparative study. The quality of the enhancement results were evaluated by measuring their Standard Deviation and Root Mean Square (RMS) Contrast.

A. Standard Deviation

$$\mathrm{STD} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(X_i - \bar{X})^2} \tag{5}$$

where X_i is a one dimensional array of N pixel intensities of the given image and $\bar{X}$ is the corresponding mean given by:

$$\bar{X} = \frac{1}{N}\sum_{i=1}^{N} X_i \tag{6}$$

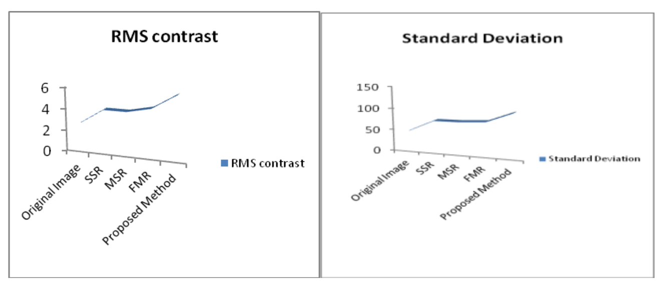
B. RMS Contrast

$$\text{RMS contrast} = \sqrt{\frac{1}{MN}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}(I_{ij} - \bar{I})^2} \tag{7}$$

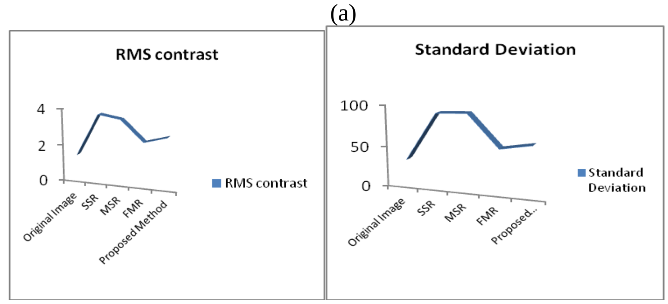
where I_{ij} is an image of size M x N whose pixel intensities are normalized in the range [0,1]. $\bar{I}$ is the mean intensity of all pixel values in the image I_{ij}.

TABLE 1: RMS contrast and Standard Deviation values achieved using SSR, MSR, FMR and the proposed method on Estampage dataset. These methods are evaluated on the standard Handwritten DIBCO datasets- HDIBCO2010, HDIBCO2014 and HDIBCO2016 .

Dataset	Measures	Original Image	SSR	MSR	FMR	FMR with Morphological processing
Estampage	RMS contrast	2.61	3.99	3.98	4.44	5.78
	Standard Deviation	45.82	72.80	73.77	77.89	101.41
HDIBCO2010	RMS contrast	1.18	3.56	3.66	2.14	2.44
	Standard Deviation	23.36	80.27	83.58	43.08	46.76
HDIBCO2014	RMS contrast	1.41	3.74	3.54	2.40	2.75
	Standard Deviation	31.79	91.47	93.42	54.11	61.12
HDIBCO2016	RMS contrast	2.43	6.09	6.21	3.31	3.52
	Standard Deviation	38.68	72.30	75.86	52.46	56.34



(a)



(b)

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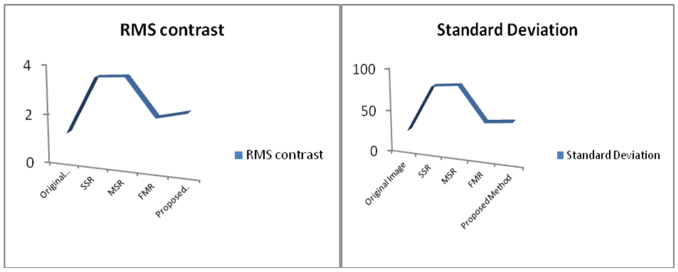
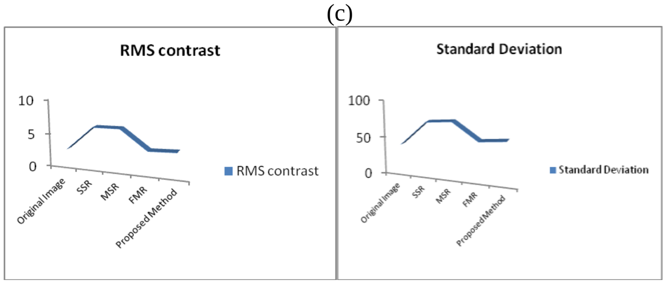


(c)



(d)

Figure 3 : RMS contrast and Standard Deviation plots on different Datasets (X-axis represents pixel intensity and Y-axis represents enhancement method). (a) Estampage (b) HDIBCO 2010 (c) HDIBCO 2014 (d) HDIBCO 2016

IV. CONCLUSION AND FUTURE SCOPE

Based on the degradation characteristics of Inscription estampage images an improved enhancement approach which integrates Morphological Processing with Frankle McCann Retinex algorithm has been implemented. This scheme highlights the text by iterative contrast stretching and suppresses the background artifacts through mathematical morphology . The results thus achieved show superior visual clarity with the best Standard Deviation and RMS contrast when compared to the traditional Retinex variants. However it was observed that the proposed method took too much of computational time. This is one issue that can be addressed in future.

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